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ICS Engineering Manual

FOR MRF PCIe-EVR-300DC

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1 Overview

At European Spallation Source (ESS), Integrated Control System (ICS) uses the Micro Research Finland (MRF) Timing System¹ as its timing system of the ESS site. The consistent and up-to-date engineering manual is essential for the ESS Timing system.

1.1 Scope

- This document identifies one of the MRF Timing Event Receivers (EVR) that needs to be configured for an ESS subsystem that needs synchronous frequencies, trigger signals and sequences of events [1].
- This document provides the generic description of the MRF PCIe-EVR-300DC and its interface board (IFB-300). In addition, it affords the minimal, essential, and generic information for the system configuration.
- The purpose of this document is to describe the engineering procedure and troubleshooting about how the MRF PCIe-EVR-300DC board will be integrated in cooperation with the new ESS EPICS Environment (E3).
- This document attempts to maintain consistency with existing ESS Timing system hardware as far as possible.

Note that this is a very early draft document and should be updated as development progresses.

1.2 Target Audience

This document is targeted to ICS engineers and technical stakeholders of the ESS timing system. It is assumed that the target audience has a technical background in the MRF Timing System, the EPICS development, and a Linux environment.

2 System Description

MRF Technical Reference [see 1, p45] explained Event Receivers and wrote :

Event Receivers decode timing events and signals from an optical event stream transmitted by an Event Generator. Events and signals are received at pre-defined rate the event clock that is usually divided down from an accelerators main RF reference. The event receivers lock to the phase event clock of the Event Generator and are thus phase locked to the RF reference. Event Receivers convert event codes transmitted by an Event Generator to hardware

¹<http://www.mrf.fi/>

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outputs. They can also generate software interrupts and store the event codes with globally distributed timestamps into FIFO memory to be read by a CPU.

ICS uses and will use the following different types of EVR :

- mTCA-EVR-300(U)
- PCIe-EVR-300DC

The scope of this document is to cover PCIe-EVR-300DC board.

2.1 PCIe-EVR-300DC

Figure 1 shows the rough physical dimensions $104 \times 79 \text{ mm}^2$ of the PCIe-EVR-300DC card. Its power dissipation is almost 10W, so one should check the maximum power of each PCIe slot where the card will be. It is advisable to have some forced cooling method to keep the temperature of the card reasonable [priv. comm.].

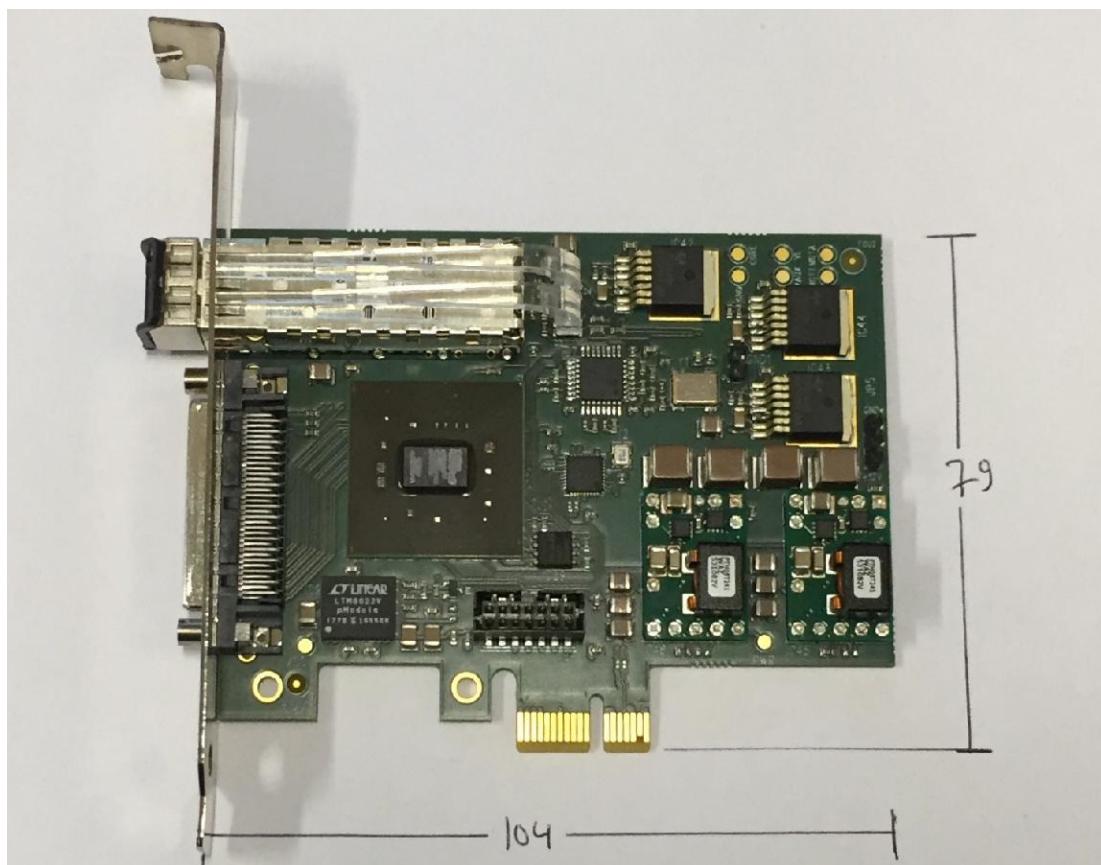


Figure 1 MRF PCIe-EVR-300DC.

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The PCIe-EVR-300DC has a SFP transceiver as an input from EVG and a micro-SCSI type connector as an output to subsystem, because of its small form factor [1]. Thus, in order to send supported type of signals to a subsystem, the interface board IFB-300 is needed. The IFB-300 has eight Universal I/O slots, shown in Figure 2. With different type of MRF Universal I/O modules, each slot can be used as an unique trigger or event signal source.

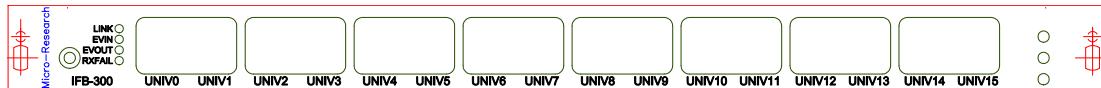


Figure 2 MRF Interface Board IFB 300 Front Panel [1].

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3 System Environment

Before describing the engineering procedure for an E3 integration of the MRF PCIe-EVR-300DC board, it is mandatory to have proper system environment that consists of specific hardware and software lists. Here we will show the hardware and software lists, their block diagrams, and their setup in the ICS lab at ESS. The information shown in this chapter is used in the ICS Lab at ESS.

3.1 Hardware

Table 1 shows the hardware list. The form factor and version of EVG can be changeable. It is assumed that the proper working EVG system is ready. The Advantech Industrial PC can be replaced with IPC, workstation, or server with a compatible PCIe slot. Note that this PCIe slot for the MRF PCIe-EVR-300DC should support more than 10W.

| Hardware | Info |
|-----------------------------------|--------------------|
| MRF PCIe-EVR-300DC | ZZB558 |
| Advantech Industrial PC | ZZB822 |
| MRF IFB-300 | ZZB437 |
| Universal I/O | |
| MRF cPCI-EVG-230 | ZZB790 |
| Ethernet, LEMO and optical cables | LC, Optical 850 nm |
| Oscilloscope | ZZB406 |

Table 1 Hardware List and Its Environment.

Figure 3 shows the Industrial PC with two PCIe-EVR-300DC installed. The IFB-300 is not shown in the figure.

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Figure 3 Industrial PC with two PCIe-EVR-300DC installed.

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3.2 Software

Table 2 shows the Software list and its environment. It is mandatory to check the kernel version, and the mrf kernel module version. Since the mrfioc2 is dependent upon devLibs2 E3 internally, an end-user is unnecessary to check its version explicitly.

| Item | Version Info. |
|-------------------|--|
| CentOS Linux | 7.5.1804 |
| Kernel | 3.10.0-862.14.4.el7.x86_64 |
| mrf kernel module | version : 1 / srcversion A998B22F1425D7388F5F7A7 |
| E3 require | 3.0.0 |
| EPICS Base | 3.15.5 |
| mrfioc2 | E3 module ver. 2.2.0-rc2 |
| devLib2 | E3 module ver. 2.9.0 |

Table 2 Software and its version information.

3.3 EVR Firmware

Table 3 shows EVR FPGA Firmware Version Register.

| | | | |
|-------------------|-----------------------------|---------------------|------------|
| EVR | FPGA | Firmware | 0x17080207 |
| Version Register | | | |
| Board Type | EVR | 0x <u>1</u> 7080207 | |
| Form Factor | PCIe | 0x <u>1</u> 7080207 | |
| EVR Subrelease ID | 8 | 0x <u>17</u> 080207 | |
| EVR Firmware ID | Delay Compensation Firmware | 0x1708 <u>02</u> 07 | |
| EVR Revision ID | 7 | 0x170802 <u>07</u> | |

Table 3 EVR FPGA Firmware Version Register in Reference [see 1, p66].

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4 Engineering Procedure

This chapter provides the minimal information to configure the EVR board properly.

4.1 System Installation

Figure 3 shows the glimpse of what system might be like in a Lab. **Note that the cable between the PCIe-EVR-300DC and IFB-300 should be connected, disconnected, or both only when powered down.** Please see the detail information in Reference [1, p54].

It is assumed that the Industrial PC is running CentOS 7 with E3. For more information on E3, please check ².

4.2 PCIe-EVR-300DC Board Identification

4.2.1 Fixing PCI IDs

The PCI ID list does not include the MRF products. It can be updated as follows:

- Cloning the sort of ESS customized PCI.IDS db:

```
iocuser@icslab-ipc01: ics_gitsrc$ git clone https://github.com/jeonghanlee/pciids
```

- Replace the pci.ids file:

```
iocuser@icslab-ipc01: pciids (master)$ bash replace-pciids.bash
centos was determined.
[sudo] password for iocuser:
```

- Check MRF products by the vendor's id (1a3e):

```
iocuser@icslab-ipc01: pciids (master)$ lspci -nnmmn | grep -E "\<(1a3e)"
02:00.0 "Signal processing controller [1180]" "Xilinx Corporation [10ee]" "XILINX PCI
DEVICE [7011]" "Micro-Research Finland Oy [1a3e]" "PCIE Event Receiver 300(DC) [172c]"
```

4.2.2 Kernel Module

The PCIE-EVR-300DC needs a kernel module to work. It can be installed by simply running some commands. Do the following:

- Go to your e3-mrfioc2 sources directory:

```
iocuser@icslab-ipc01: ~$ cd e3/e3-mrfioc2
```

- Install the kernel module:

²<https://github.com/icshwi/e3training>

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```
iocuser@icslab-ipc01: e3-mrfioc2 (master)$ make dkms_add
/epics/base-3.15.5/bin/linux-x86_64/msi -M name="mrfioc2" -M version="2.2.0-rc2" -M
    kmod_name="mrf" /home/iocuser/e3/e3-mrfioc2/dkms/dkms_with_msi.conf.in > /home/iocuser/
        e3/e3-mrfioc2/dkms/dkms_with_msi.conf
sudo install -d /usr/src/mrfioc2-2.2.0-rc2
sudo cp -r /home/iocuser/e3/e3-mrfioc2/mrfioc2/mrmShared/linux/* /usr/src/mrfioc2-2.2.0-rc2
/
sudo /usr/sbin/dkms add -m mrfioc2 -v 2.2.0-rc2

Creating symlink /var/lib/dkms/mrfioc2/2.2.0-rc2/source ->
    /usr/src/mrfioc2-2.2.0-rc2

DKMS: add completed.

iocuser@icslab-ipc01: e3-mrfioc2 (master)$ make dkms_build
sudo /usr/sbin/dkms build -m mrfioc2 -v 2.2.0-rc2

Kernel preparation unnecessary for this kernel. Skipping...

Building module:
cleaning build area...
make -j4 KERNELRELEASE=3.10.0-862.14.4.el7.x86_64 -C /lib/modules/3.10.0-862.14.4.el7.
    x86_64/build M=/var/lib/dkms/mrfioc2/2.2.0-rc2/build modules...
cleaning build area...

DKMS: build completed.

iocuser@icslab-ipc01: e3-mrfioc2 (master)$ make dkms_install
sudo /usr/sbin/dkms install -m mrfioc2 -v 2.2.0-rc2
mrf.ko.xz:
Running module version sanity check.
- Original module
  - No original module exists within this kernel
- Installation
  - Installing to /lib/modules/3.10.0-862.14.4.el7.x86_64/extr/
Adding any weak-modules

depmod...

DKMS: install completed.

iocuser@icslab-ipc01: e3-mrfioc2 (master)$ make setup
KERNEL=="uio*", ATTR{name}=="mrf-pci", MODE="0666"
mrf
rmmod mrf
rmmod parport
rmmod uio
insmod /lib/modules/3.10.0-862.14.4.el7.x86_64/kernel/drivers/parport/parport.ko.xz
insmod /lib/modules/3.10.0-862.14.4.el7.x86_64/kernel/drivers/uio/uio.ko.xz
insmod /lib/modules/3.10.0-862.14.4.el7.x86_64/extr/mrf.ko.xz

It is OK to see "E3/RULES_DKMS:37: recipe for target 'setup' failed"
-----
crw-rw-rw-. 1 root root 241, 0 Dec 13 10:11 /dev/uio0
crw-rw-rw-. 1 root root 241, 1 Dec 13 10:11 /dev/uio1
-----
```

- Check kernel module information:

```
iocuser@icslab-ipc01: pciids (master)$ lsmod |grep mrf
mrf                  18137   0
parport              46395   1 mrf
uio                  19338   1 mrf
```

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```
iocuser@icslab-ipc01: pciids (master)$ modinfo mrf
filename:      /lib/modules/3.10.0-862.14.4.el7.x86_64/extr/mrf.ko.xz
author:        Michael Davidsaver <mdavidsaver@gmail.com>
version:       1
license:       GPL v2
retpoline:     Y
rhelversion:   7.5
srcversion:    A998B22F1425D7388F5F7A7
alias:         pci:v000010EEd00007011sv00001A3Esd0000132Cbc*sc*i*
alias:         pci:v00001A3Ed0000152Csv00001A3Esd0000152Cbc*sc*i*
alias:         pci:v00001A3Ed0000252Csv00001A3Esd0000252Cbc*sc*i*
alias:         pci:v000010EEd00007011sv00001A3Esd0000172Cbc*sc*i*
alias:         pci:v00001204d0000EC30sv00001A3Esd0000172Cbc*sc*i*
alias:         pci:v000010B5d00009056sv00001A3Esd0000192Cbc*sc*i*
alias:         pci:v000010B5d00009030sv00001A3Esd000011E6bc*sc*i*
alias:         pci:v000010B5d00009030sv00001A3Esd000020E6bc*sc*i*
alias:         pci:v000010B5d00009030sv00001A3Esd000020DCbc*sc*i*
alias:         pci:v000010B5d00009030sv00001A3Esd000010E6bc*sc*i*
depends:      parport,uio
vermagic:     3.10.0-862.14.4.el7.x86_64 SMP mod_unload modversions
parm:         cable:Name of JTAG parallel port cable to emulate (charp)
parm:         interfaceversion:User space interface version (int)
parm:         use_msi:Use MSI if present (default 1, yes) (uint)
```

4.2.3 PCI Addressing

Each PCI device is identified by a domain, a bus, a device, and a function number in Linux. Therefore, in order to initialize the MRF PCIe-EVR-300DC board in E3, one needs the following information: a bus number, a device number, and a function number. These numbers are the parameters of a `mrmEvrSetupPCI` function.

One can use `lspci` to find them as follows:

```
iocuser@icslab-ipc01: ~$ lspci
...
02:00.0 Signal processing controller: Xilinx Corporation XILINX PCI DEVICE
...
iocuser@icslab-ipc01: ~$ lspci -s 02:00.0 -vv
02:00.0 Signal processing controller: Xilinx Corporation XILINX PCI DEVICE
    Subsystem: Micro-Research Finland Oy PCIE Event Receiver 300(DC)
    Control: I/O+ Mem+ BusMaster+ SpecCycle- MemWINV- VGASnoop- ParErr- Stepping- SERR- FastB2B-
              DisINTx+
    Status: Cap+ 66MHz- UDF- FastB2B- ParErr- DEVSEL=fast >TAbort- <TAbsr- <MAbort- >SERR- <PERR-
              INTx-
    Latency: 0
    Interrupt: pin A routed to IRQ 337
    Region 0: Memory at df300000 (32-bit, non-prefetchable) [size=256K]
    Capabilities: <access denied>
    Kernel driver in use: mrf-pci
    Kernel modules: mrf
```

And one should identify four number as follows:

```
iocuser@icslab-ipc01: ~$ lspci -s 02:00.0 -t
+-[0000:02]---00.0
 \-[0000:00]-
```

, where `--[0000:02]---00.0` can be translated to `--[domain:bus]---device.function`. Thus in the above case, four numbers are shown in Table 4.

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| | | |
|----------|--|-----|
| bus | | 0x2 |
| device | | 0x0 |
| function | | 0x0 |

Table 4 MRF PCIe-EVR-300DC Identification Numbers

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4.3 EPICS IOC Setup under E3

In order to start the EPICS IOC for the MRF PCIE-EVR-300DC under E3, one should consider the following things: 1) the EPICS database file, and 2) the EPICS start-up script. The working directory, where an user can create, e.g., in the ICS Lab,

```
/home/iocuser/e3/mrfioc2/cmds
```

Listing 4.1 Working Directory in the ICS lab.

4.3.1 EPICS Database File

The database file in E3 is located in the following location:

```
/epics/base-3.15.5/require/3.0.0/siteMods/mrfioc2/2.2.0-rc2/db/evr-pcie-300dc-ess.db
```

4.3.2 Start-Up Script

Listing 4.2 shows the IOC start-up script which has the MRF PCIE-EVR-300DC Identification Numbers, as explained in the previous step.

```
require mrfioc2,2.2.0-rc2

epicsEnvSet("IOC", "EMPCIEEV300DC")
epicsEnvSet("DEV1", "EVRO")

epicsEnvSet("ESSEvtClockRate" "88.0525")

mrmEvrSetupPCI("$(DEV1)", "02:00.0")
dbLoadRecords("evr-pcie-300dc-ess.db", "EVR=$(DEV1), SYS=$(IOC), D=$(DEV1), FEVT=$(ESSEvtClockRate)
")

# needed with software timestamp source w/o RT thread scheduling
var evrMrmTimeNSOverflowThreshold 100000

iocInit()

# Set delay compensation to 70 ns, needed to avoid timestamp issue
dbpf $(IOC)-$(DEV1):DC-Tgt-SP 70
```

Listing 4.2 Start-up script `empcieevr300dc.cmd`. Line 8 should be matched to Table 4 as `mrmEvrSetupPCI($(DEV1), "bus:device.function")`.

4.3.3 EPICS IOC

All the EPICS parameters should be run from an E3 session. To start E3, type:

```
iocuser@icslab-ipc01: cmds (master)$ source /epics/base-3.15.5/require/3.0.0/bin/setE3Env.bash
```

All the IOCs and related EPICS commands (caget, caput, camonitor, etc.) should be run from an E3 session.

Under E3, the EPICS IOC can be started via the command `iocsh.bash empcieevr300dc.cmd`. The output should look like as follows:

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```
iocuser@icslab-ipc01: cmd$ iocsh.bash empcieevr300dc.cmd
#
# Start at "2019-W02-Jan07-1127-54-CET"
#
# Version information:
# European Spallation Source ERIC : iocsh.bash (v0.3.1-6690f8a.PID-10491)
#
# --->--> snip -->-->
# Please Use Version and other environment variables
# in order to report or debug this shell
#
# HOSTDISPLAY=""
# WINDOWID=""
# PWD="/home/iocuser/e3/e3-mrfioc2/cmds"
# USER="iocuser"
# LOGNAME="iocuser"
# EPICS_HOST_ARCH="linux-x86_64"
# EPICS_BASE="/epics/base-3.15.5"
# E3_REQUIRE_NAME="require"
# E3_REQUIRE_VERSION="3.0.0"
# E3_REQUIRE_LOCATION="/epics/base-3.15.5/require/3.0.0"
# E3_REQUIRE_BIN="/epics/base-3.15.5/require/3.0.0/bin"
# E3_REQUIRE_DB="/epics/base-3.15.5/require/3.0.0/db"
# E3_REQUIRE_DBD="/epics/base-3.15.5/require/3.0.0/dbd"
# E3_REQUIRE_INC="/epics/base-3.15.5/require/3.0.0/include"
# E3_REQUIRE_LIB="/epics/base-3.15.5/require/3.0.0/lib"
# E3_SITEAPPS_PATH="/epics/base-3.15.5/require/3.0.0/siteApps"
# E3_SITELIBS_PATH="/epics/base-3.15.5/require/3.0.0/siteLibs"
# E3_SITEMODS_PATH="/epics/base-3.15.5/require/3.0.0/siteMods"
# EPICS_DRIVER_PATH="/epics/base-3.15.5/require/3.0.0/siteMods"
# EPICS_CA_AUTO_ADDR_LIST=""
# EPICS_CA_ADDR_LIST=""
# PATH="/epics/base-3.15.5/require/3.0.0/bin:/epics/base-3.15.5/bin/linux-x86_64:/usr/local/bin:/usr/bin:/usr/local/sbin:/usr/sbin:/home/iocuser/.local/bin:/home/iocuser/bin"
# LD_LIBRARY_PATH="/epics/base-3.15.5/lib/linux-x86_64:/epics/base-3.15.5/require/3.0.0/lib/linux-x86_64:/epics/base-3.15.5/require/3.0.0/siteLibs/linux-x86_64"
# --->--> snip -->-->
#
# Set REQUIRE_IOC for its internal PVs
epicsEnvSet REQUIRE_IOC "E3R:ICSLAB-IPCO1"
#
# Set E3_IOCSH_TOP for the absolute path where iocsh.bash is executed.
epicsEnvSet E3_IOCSH_TOP "/home/iocuser/e3/e3-mrfioc2/cmds"
#
#
# Load require module, which has the version 3.0.0
#
dlload /epics/base-3.15.5/require/3.0.0/lib/linux-x86_64/librequire.so
dbLoadDatabase /epics/base-3.15.5/require/3.0.0/dbd/require.dbd
require_registerRecordDeviceDriver
Loading module info records for require
#
# Set E3_CMD_TOP for the absolute path where empcieevr300dc.cmd exists
epicsEnvSet E3_CMD_TOP "/home/iocuser/e3/e3-mrfioc2/cmds"
#
iocshLoad 'empcieevr300dc.cmd','
require mrfioc2,2.2.0-rc2
Module mrfioc2 version 2.2.0-rc2 found in /epics/base-3.15.5/require/3.0.0/siteMods/mrfioc2/2.2.0-rc2/
Module mrfioc2 depends on devlib2 2.9.0
Module devlib2 version 2.9.0 found in /epics/base-3.15.5/require/3.0.0/siteMods/devlib2/2.9.0/
```

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```

Loading library /epics/base-3.15.5/require/3.0.0/siteMods/devlib2/2.9.0/lib/linux-x86_64/
    libdevlib2.so
Loaded devlib2 version 2.9.0
Loading dbd file /epics/base-3.15.5/require/3.0.0/siteMods/devlib2/2.9.0/dbd/devlib2.dbd
Calling function devlib2_registerRecordDeviceDriver
Loading module info records for devlib2
Loading library /epics/base-3.15.5/require/3.0.0/siteMods/mrfioc2/2.2.0-rc2/lib/linux-x86_64/
    libmrfioc2.so
Loaded mrfioc2 version 2.2.0-rc2
Loading dbd file /epics/base-3.15.5/require/3.0.0/siteMods/mrfioc2/2.2.0-rc2/dbd/mrfioc2.dbd
Calling function mrfioc2_registerRecordDeviceDriver
Loading module info records for mrfioc2
epicsEnvSet("IOC", "EMPCIEEV300DC")
epicsEnvSet("DEV1", "EVRO")
#epicsEnvSet("MainEvtCODE" "14")
#epicsEnvSet("HeartBeatEvtCODE" "122")
epicsEnvSet("ESSEvtClockRate" "88.0525")
mrmEvrSetupPCI("EVRO", "02:00.0")
Notice: devPCIFindSpec() expect B:D.F in hex
Device EVRO 2:0.0 slot=(null)
Using IRQ 81
FWVersion 0x17080207
Found version 519
Found SFP EEPROM
Sequencer capability detected
PCIe: Out FP:0 FPUNIV:16 RB:0 IFP:16 GPIO:0
Enabling interrupts
dbLoadRecords("evr-pcie-300dc-ess.db", "EVRO, SYS=EMPCIEEV300DC, D=EVRO, FEVT=88.0525")
EVRO FIFO task start
# needed with software timestamp source w/o RT thread scheduling
var evrMrmTimeNSOverflowThreshold 100000
iocInit()
Starting iocInit
#####
## EPICS R3.15.5-E3-3.15.5-patch
## EPICS Base built Jun 15 2018
#####
Set EVR clock 88052500.000000
iocRun: All initialization complete
# Set delay compensation to 70 ns, needed to avoid timestamp issue
dbpf EMPCIEEV300DC-EVRO:DC-Tgt-SP 70
DBR_DOUBLE: 70
# Set the IOC Prompt String One
epicsEnvSet IOCSH_PS1 "6690f8a.icslab-ipc01.10506 > "
#
6690f8a.icslab-ipc01.10506 >

```

In addition, the PCI information is available within the running IOC via `devPCIShow` as follows:

```
6690f8a.icslab-ipc01.10506 > devPCIShow
```

Look for the line with your configuration information, in our case is:

```
PCI 0000:02:00.0 IRQ 81
    vendor:device 10ee:7011 rev 00
```

Where the vendor id 10ee is Xilinx Corporation. And show the PCI information with (the second parameter is the verbosity level):

```
6690f8a.icslab-ipc01.10506 > devPCIShow 9 0x10ee
...
```

```
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Classification ESS Use Only
```

```
PCI 0000:02:00.0 IRQ 81
vendor:device 10ee:7011 rev 00
subvdev:subdev 1a3e:172c
class 118000 generic signal processing controller
driver mrf-pci
BAR 0 32-bit MMIO    256 kB
...
```

4.3.4 Checking automatic configuration after reboot

Reboot and check that the module is loaded and the IOC correctly starts:

```
iocuser@icslab-ipc01: ~$ lsmod |grep mrf
mrf                  18137  0
uio                  19338  1 mrf
parport              46395  1 mrf
```

Also try restarting the IOC as before, the output should be the same.

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5 System In-Situ Verification and Configuration Procedure

This chapter provides the minimal system verification procedure. If one wants to do more step-by-step procedure which may be useful when testing the function of hardware and software, please see Reference [see 2, p14]. It also explains how to configure the EVR according to one's needs.

| Step | Goal | Info. |
|------|--|--|
| 1 | Check the EVR & EVG connection | Link status, link clock, and heartbeat timeout counter |
| 2 | Monitor receiving and acknowledging events | Event counter and receiving event frequency |
| 3 | Generate trigger signals from EVR | Various trigger signals with an oscilloscope |
| 4 | Configure hardware timestamps | Timestamps from the EVG |
| 5 | Use the EVR in standalone mode | Use the EVR without an EVG |
| 6 | Generate events from the inputs | Use the inputs |

Table 5 System In-Situ Verification Procedure

5.1 Step 1 : Check the EVR and EVG connection

This assumes that the EVR is connected to a properly configured EVG. Short comments on each command or a series of commands are shown before the corresponding command.

```
#  
# We can check the EVG and EVR link status and the link clock setting,  
# and can also see the link down counter as well.  
#  
iocuser@icslab-ipc01: ~$ caget EMPCIEEVR300DC-EVRO:Link-Sts  
EMPCIEEVR300DC-EVRO:Link-Sts      OK  
iocuser@icslab-ipc01: ~$ caget EMPCIEEVR300DC-EVRO:Link-Clk-I  
EMPCIEEVR300DC-EVRO:Link-Clk-I    88.0519  
#  
# Change the wrong clock setting on EVR, then we expect that the link status will be Fail.  
#  
iocuser@icslab-ipc01: ~$ caput EMPCIEEVR300DC-EVRO:Link-Clk-SP 100  
Old : EMPCIEEVR300DC-EVRO:Link-Clk-SP  88.0525  
New : EMPCIEEVR300DC-EVRO:Link-Clk-SP  100  
iocuser@icslab-ipc01: ~$ caget EMPCIEEVR300DC-EVRO:Link-Sts  
EMPCIEEVR300DC-EVRO:Link-Sts      Fail  
iocuser@icslab-ipc01: ~$ caget EMPCIEEVR300DC-EVRO:Link-Clk-I  
EMPCIEEVR300DC-EVRO:Link-Clk-I    100
```

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```

#
# Revert it back to the proper clock setting, and the link status will be OK.
#
iocuser@icslab-ipc01: ~$ caput EMPCIEEV300DC-EVRO:Link-Clk-SP 88.0525
Old : EMPCIEEV300DC-EVRO:Link-Clk-SP 100
New : EMPCIEEV300DC-EVRO:Link-Clk-SP 88.0525
iocuser@icslab-ipc01: ~$ caget EMPCIEEV300DC-EVRO:Link-Sts
EMPCIEEV300DC-EVRO:Link-Sts      OK
iocuser@icslab-ipc01: ~$ caget EMPCIEEV300DC-EVRO:Link-Clk-I
EMPCIEEV300DC-EVRO:Link-Clk-I 88.0519
#
# The link heartbeat counter is 35
#
iocuser@icslab-ipc01: ~$ camonitor EMPCIEEV300DC-EVRO:Cnt-LinkTimo-I
EMPCIEEV300DC-EVRO:Cnt-LinkTimo-I 2019-01-03 14:59:19.909288 35
#
# Open another terminal, to change the wrong link clock.
#
iocuser@icslab-ipc01: ~$ caput EMPCIEEV300DC-EVRO:Link-Clk-SP 100
Old : EMPCIEEV300DC-EVRO:Link-Clk-SP 88.0525
New : EMPCIEEV300DC-EVRO:Link-Clk-SP 100
#
# So, the heartbeat counter should be increasing as follows:
#
EMPCIEEV300DC-EVRO:Cnt-LinkTimo-I 2019-01-03 15:07:40.035069 36
EMPCIEEV300DC-EVRO:Cnt-LinkTimo-I 2019-01-03 15:07:41.316697 37
EMPCIEEV300DC-EVRO:Cnt-LinkTimo-I 2019-01-03 15:07:42.597370 38
EMPCIEEV300DC-EVRO:Cnt-LinkTimo-I 2019-01-03 15:07:43.877849 39
EMPCIEEV300DC-EVRO:Cnt-LinkTimo-I 2019-01-03 15:07:45.158539 40
#
# The counter will be stopped after the proper value is given.
# In the second terminal:
#
iocuser@icslab-ipc01: ~$ caput EMPCIEEV300DC-EVRO:Link-Clk-SP 88.0525
Old : EMPCIEEV300DC-EVRO:Link-Clk-SP 100
New : EMPCIEEV300DC-EVRO:Link-Clk-SP 88.0525
#
# Also check that the EVG is sending a timestamp.
#
iocuser@icslab-ipc01: ~$ caget EMPCIEEV300DC-EVRO:Time-Valid-Sts
EMPCIEEV300DC-EVRO:Time-Valid-Sts Valid

```

5.2 Step 2 : Monitor receiving and acknowledging events

This assumes that the EVG is sending event 14 at 14 Hz. Short comments on each command or a series of commands are shown before the corresponding command.

```

1 #
2 # Monitor the event counter E (14) and check the time difference between counters, e.g., 20616 and
3 # 20617, is 0.071429s, i.e., 14 Hz.
4 iocuser@icslab-ipc01: ~$ camonitor EMPCIEEV300DC-EVRO:EvtECnt-I
5 EMPCIEEV300DC-EVRO:EvtECnt-I 2019-01-03 15:15:29.614903 20616
6 EMPCIEEV300DC-EVRO:EvtECnt-I 2019-01-03 15:15:29.686332 20617
7 EMPCIEEV300DC-EVRO:EvtECnt-I 2019-01-03 15:15:29.757761 20618
8 EMPCIEEV300DC-EVRO:EvtECnt-I 2019-01-03 15:15:29.829190 20619
9 EMPCIEEV300DC-EVRO:EvtECnt-I 2019-01-03 15:15:29.900619 20620

```

| | |
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5.3 Step 3 : Generate trigger signals from EVR

An EVR is composed of several logical sub-units, and one of the logical sub-units is the pulse generator (or delay generator). Each pulse generator has an associated Delay and Width [2]. In the following procedure, two pulse generators are mapped to the OutFPUV00 and OutFPUV01 of a PCIE-EVR-300DC, which are connected to the channel 1 and 2 of the oscilloscope respectively in order to see whether output signals are generated according to Delay's and Width's changes. This assumes that the EVG is sending event 14 at 14 Hz. Short comments on each command or a series of commands are shown before the corresponding command.

5.3.1 OutFPUV00 output

```

#
# Set OutFPUV00 to trigger on pulse generator 0
#
iocuser@icslab-ipc01: ~$ caput EMPCIEEVR300DC-EVRO:OutFPUV00-Src-SP 0
Old : EMPCIEEVR300DC-EVRO:OutFPUV00-Src-SP 61
New : EMPCIEEVR300DC-EVRO:OutFPUV00-Src-SP 0
#
# Set pulse generator 0 to trigger on event 14
#
iocuser@icslab-ipc01: ~$ caput EMPCIEEVR300DC-EVRO:DlyGen0-Evt-Trig0-SP 14
Old : EMPCIEEVR300DC-EVRO:DlyGen0-Evt-Trig0-SP 0
New : EMPCIEEVR300DC-EVRO:DlyGen0-Evt-Trig0-SP 14
#
# Set the width of pulse generator 0. 10 000 is translated to 10 ms.
#
iocuser@icslab-ipc01: ~$ caput EMPCIEEVR300DC-EVRO:DlyGen0-Width-SP 10000
Old : EMPCIEEVR300DC-EVRO:DlyGen0-Width-SP 0
New : EMPCIEEVR300DC-EVRO:DlyGen0-Width-SP 10000

```

Figure 4 shows the output of OutFPUV00 in an oscilloscope.

5.3.2 Width Time of Pulse Generator

```

#
# Change the width of pulse generator 0 from 10 ms to 50 ms
#
iocuser@icslab-ipc01: ~$ caput EMPCIEEVR300DC-EVRO:DlyGen0-Width-SP 50000
Old : EMPCIEEVR300DC-EVRO:DlyGen0-Width-SP 10000
New : EMPCIEEVR300DC-EVRO:DlyGen0-Width-SP 50000

```

and the output is shown in Figure 5.

And one can also check them via EMPCIEEVR300DC-EVRO:DlyGen0-Width-RB as follows:

```

#
# Change the width time to 50 ms, 40 ms, and 80 ms in another terminal, and
# check that the Read Back (RB) value is changing.
#
iocuser@icslab-ipc01: ~$ camonitor EMPCIEEVR300DC-EVRO:DlyGen0-Width-RB
EMPCIEEVR300DC-EVRO:DlyGen0-Width-RB 2019-01-03 16:01:48.506108 50000
EMPCIEEVR300DC-EVRO:DlyGen0-Width-RB 2019-01-03 16:03:18.294459 40000
EMPCIEEVR300DC-EVRO:DlyGen0-Width-RB 2019-01-03 16:03:21.788930 80000

```

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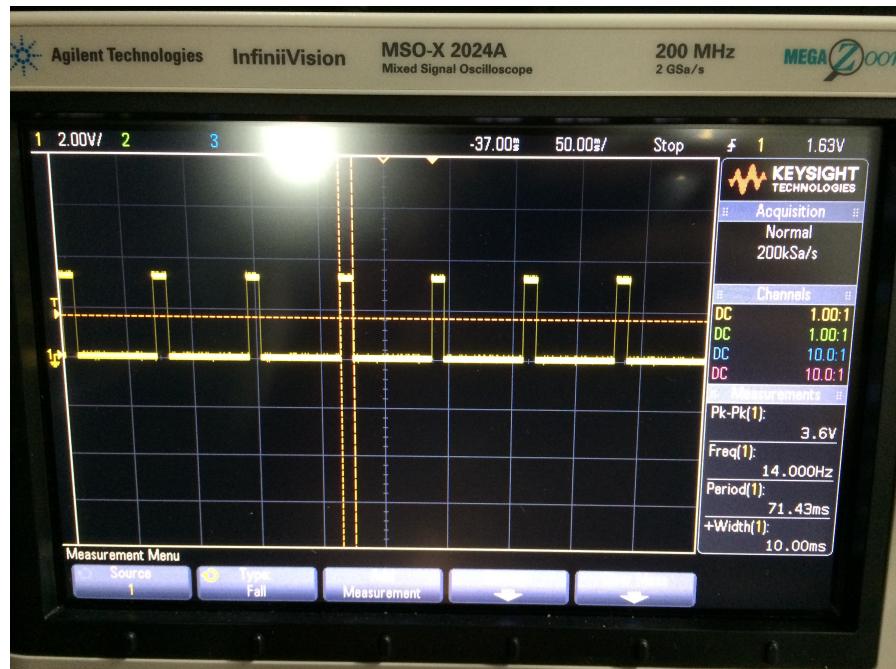


Figure 4 14 Hz signal with 10 ms width

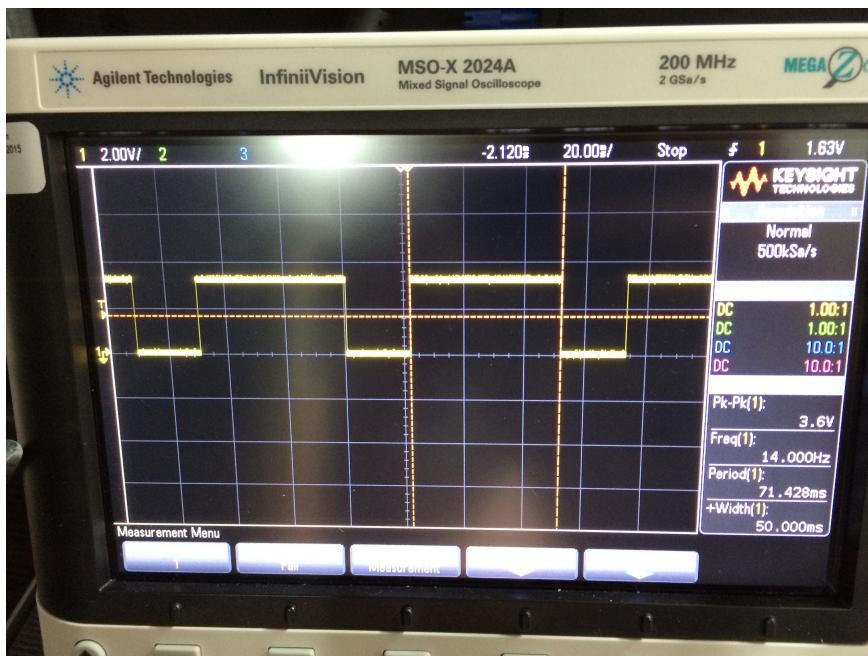


Figure 5 14 Hz signal with 50 ms width

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5.3.3 Delay Time of Pulse Generator

```

#
# Set the width time - 20 ms - of pulse generator 0
#
iocuser@icslab-ipc01: ~$ caput EMPCIEEV300DC-EVRO:DlyGen0-Width-SP 20000
Old : EMPCIEEV300DC-EVRO:DlyGen0-Width-SP 8000
New : EMPCIEEV300DC-EVRO:DlyGen0-Width-SP 20000
#
# Set OutFPUV01 to trigger on pulse generator 1
#
iocuser@icslab-ipc01: ~$ caput EMPCIEEV300DC-EVRO:OutFPUV01-Src-SP 1
Old : EMPCIEEV300DC-EVRO:OutFPUV01-Src-SP 61
New : EMPCIEEV300DC-EVRO:OutFPUV01-Src-SP 1
#
# Set pulse generator 1 to trigger on event 14
#
iocuser@icslab-ipc01: ~$ caput EMPCIEEV300DC-EVRO:DlyGen1-Evt-Trig0-SP 14
Old : EMPCIEEV300DC-EVRO:DlyGen1-Evt-Trig0-SP 0
New : EMPCIEEV300DC-EVRO:DlyGen1-Evt-Trig0-SP 14
#
# Set the width time - 20 ms - of pulse generator 1
#
iocuser@icslab-ipc01: ~$ caput EMPCIEEV300DC-EVRO:DlyGen1-Width-SP 20000
Old : EMPCIEEV300DC-EVRO:DlyGen1-Width-SP 0
New : EMPCIEEV300DC-EVRO:DlyGen1-Width-SP 20000
#
# Set the delay time - 30 ms - of pulse generator 1
#
iocuser@icslab-ipc01: ~$ caput EMPCIEEV300DC-EVRO:DlyGen1-Delay-SP 30000
Old : EMPCIEEV300DC-EVRO:DlyGen1-Delay-SP 0
New : EMPCIEEV300DC-EVRO:DlyGen1-Delay-SP 30000

```

Figure 6 shows the result.

The configuration of the outputs and pulse generators can be added to the startup script after `iocInit()` replacing `caput` by `dbpf`.

5.4 Step 4 : Configure hardware timestamps

This section provides the minimal information to configure an IOC to get its timestamps from the timing system. More information about timestamping can be found in the document ESS-0085848. Short comments on each command or a series of commands are shown before the corresponding command.

```

#
# Set up the Time-I record to process on arrival of event 14
#
iocuser@icslab-ipc01: ~$ caput EMPCIEEV300DC-EVRO:Time-I.EVNT 14
Old : EMPCIEEV300DC-EVRO:Time-I.EVNT 125
New : EMPCIEEV300DC-EVRO:Time-I.EVNT 14
#
# Set up the Time-I record to use the hardware timestamp of event 14
#
iocuser@icslab-ipc01: ~$ caput EMPCIEEV300DC-EVRO:Time-I.INP "@OBJ=EVRO, Code=14"
Old : EMPCIEEV300DC-EVRO:Time-I.INP    @OBJ=EVRO, Code=125
New : EMPCIEEV300DC-EVRO:Time-I.INP    @OBJ=EVRO, Code=14
#
# Set up your records to use the timestamp from the Time-I record
#

```

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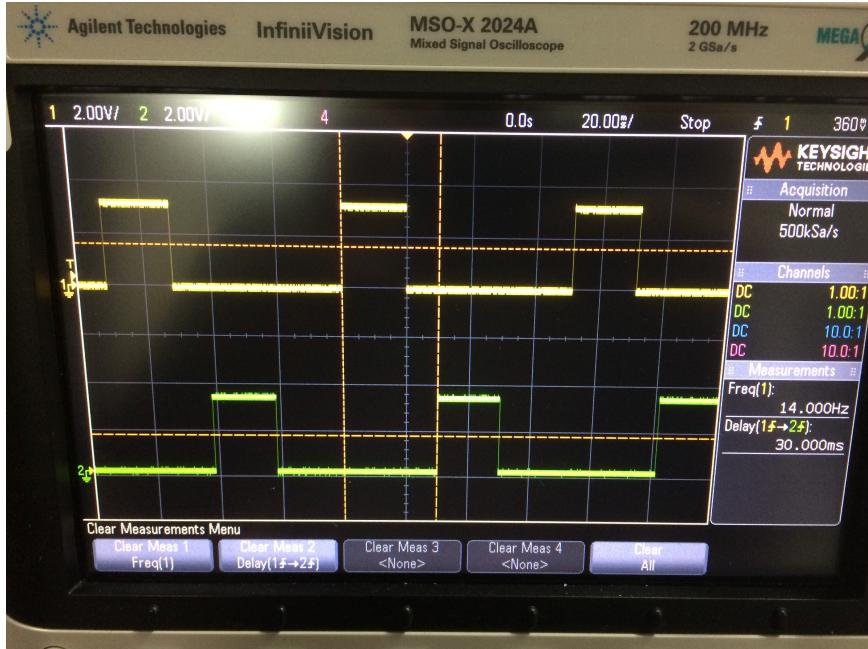


Figure 6 Two 14 Hz signals with 30 ms delay

```
iocuser@icslab-ipc01: ~$ caput exemplerecord.TSEL EMPCIEEVR300DC-EVRO:Time-I.TIME
Old : exemplerecord.TSEL
New : exemplerecord.TSEL          EMPCIEEVR300DC-EVRO:Time-I.TIME NPP NMS
#
# Check that your records have the same timestamp as event 14
#
iocuser@icslab-ipc01: ~$ caget -a exemplerecord EMPCIEEVR300DC-EVRO:EvtECnt-I
exemplerecord      2019-01-04 11:21:17.183434 1171
EMPCIEEVR300DC-EVRO:EvtECnt-I    2019-01-04 11:21:17.183434 3385
```

5.4.1 Configure the exact tick period

The timing system stores internally the timestamps as ticks, that then EPICS translates to wall-clock time. To do this the IOC should be configured with the actual tick period. By default it assumes that the event link frequency is being generated by the EVG fractional synthesizer. If the EVG takes the event frequency from an external source through its inputs, the exact frequency has to be set in the EVR IOC.

```
#
# Set the exact event frequency
#
iocuser@icslab-ipc01: ~$ caput EMPCIEEVR300DC-EVRO:Time-Clock-SP 88.0525
Old : EMPCIEEVR300DC-EVRO:Time-Clock-SP 0
New : EMPCIEEVR300DC-EVRO:Time-Clock-SP 88.0525
```

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5.5 Step 5 : Use the EVR in standalone mode

The EVR can work on its own without a connection to an EVG, but with reduced functionality. Here it is shown how to configure the EVR to work in this way. Some of the settings need to be included in the startup script shown in Listing 4.2, after `iocInit()`, so it is advised to include all the configuration in that file. Short comments on each command or a series of commands are shown before the corresponding command.

```
### Get current time from system clock, this will be used for the timestamps #####
dbpf $(IOC)-$(DEV1):TimeSrc-Sel "Sys. Clock"

### Set up the prescaler that will trigger the sequencer at 14 Hz #####
# The value of the prescaler is the integer which gives the expected frequency (14 Hz in this
# example) when the event frequency (88.0525 MHz for ESS) is divided by the integer: 88.0525
# MHz / 6289464 = 14 Hz
dbpf $(IOC)-$(DEV1):PS0-Div-SP 6289464

### Set up the sequencer #####
# Set the runmode to normal, so that the sequencer re-arms after it finishes running
dbpf $(IOC)-$(DEV1):SoftSeq0-RunMode-Sel "Normal"
# Set the trigger of the sequencer as prescaler 0
dbpf $(IOC)-$(DEV1):SoftSeq0-TrigSrc-2-Sel "Prescaler 0"
# Set the engineering units (microseconds) for the delay of the events in the sequence (sequence
# timestamps) used in configure_sequencer_14Hz.sh; more information below
dbpf $(IOC)-$(DEV1):SoftSeq0-TsResolution-Sel "uSec"
# Attach the soft sequence to a specific hardware sequence
dbpf $(IOC)-$(DEV1):SoftSeq0-Load-Cmd 1
# Enable the sequencer
dbpf $(IOC)-$(DEV1):SoftSeq0-Enable-Cmd 1

### Run the script that configures the events and timestamps of the sequence, more information
# below #####
system("/bin/sh ./configure_sequencer_14Hz.sh $(IOC) $(DEV1)")
```

The file `configure_sequencer_14Hz.sh` shown in Listing 5.1 should be located in the same directory as `empcieevr300dc.cmd`; it specifies what events and with what delay after the sequencer is triggered (what is known as sequencer timestamps) the events should be sent:

```
### Bash script to configure the EVG/EVR sequencer
### All values in us, as configured with $1-$2:SoftSeq0-TsResolution-Sel

### Set up the sequence content, events and timestamps
### Event 127 is always needed at the end, it is the end-of-sequence event and stops the sequencer
### The first event in the its list is sent with the first delay in its list, the second event
# after the second delay (the start of time is always the moment when the sequencer is
# triggered) and so on
### The timestamps should be monotonically increasing
# Event code 14 (14 Hz), 127 is the end of sequence
caput -a $1-$2:SoftSeq0-EvtCode-SP 2 14 127
# Defining time at which the event codes are sent in us (timestamps), as configured with $1-$2:
# SoftSeq0-TsResolution-Sel
caput -a $1-$2:SoftSeq0-Timestamp-SP 2 0 1

# Commit the sequence to HW
caput $1-$2:SoftSeq0-Commit-Cmd 1
```

Listing 5.1 Sequencer population file `configure_sequencer_14Hz.sh`.

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For more information, please check ESS-XXXXXXX (ICS Engineering Manual for MRF cPCI-EVG-230), the EVR sequencer acts in exactly the same way as the EVG sequencer, but the EVR only has one sequencer.

5.6 Step 6 : Generate events from the inputs

The PCIE-EVR-300DC can use its first Universal I/O module slot of the IFB-300 with an Input module with two inputs that can be used to trigger events, which can be timestamped or used to trigger processing or sequencers. In future versions of the PCIE-EVR-300DC firmware this will be extended to the rest of the slots. Short comments on each command or a series of commands are shown before the corresponding command.

```

#
# Set to high impedance the output line that shares channel with the input
#
iocuser@icslab-ipc01: ~$ caput EMPCIEEVR300DC-EVRO:OutFPUV00-Src-SP 61
Old : EMPCIEEVR300DC-EVRO:OutFPUV00-Src-SP 61
New : EMPCIEEVR300DC-EVRO:OutFPUV00-Src-SP 61
#
# Set FPI0 to generate an event on the rising edge of the input signal
#
iocuser@icslab-ipc01: ~$ caput EMPCIEEVR300DC-EVRO:In0-Trig-Ext-Sel "Edge"
Old : EMPCIEEVR300DC-EVRO:In0-Trig-Ext-Sel Off
New : EMPCIEEVR300DC-EVRO:In0-Trig-Ext-Sel Edge
iocuser@icslab-ipc01: ~$ caput EMPCIEEVR300DC-EVRO:In0-Edge-Sel "Active Rising"
Old : EMPCIEEVR300DC-EVRO:In0-Edge-Sel Active Rising
New : EMPCIEEVR300DC-EVRO:In0-Edge-Sel Active Rising
#
# Select the event number to be generated
#
iocuser@icslab-ipc01: ~$ caput EMPCIEEVR300DC-EVRO:In0-Code-Ext-SP 10
Old : EMPCIEEVR300DC-EVRO:In0-Code-Ext-SP 0
New : EMPCIEEVR300DC-EVRO:In0-Code-Ext-SP 10

```

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6 Troubleshooting

This chapter has trial and error while installing and configuring the MRF PCIE-EVR-300DC.

6.1 PCI error

If the device file permission is wrong, one can see the following error:

```
mrmEvrSetupPCI("EVRO", "02:00.0")
Notice: devPCIFindSpec() expect B:D.F in hex
Device EVRO 2:0.0 slot=(null)
Using IRQ 81
Can neither open resource file nor uio file of PCI device 0000:02:00.0 BAR 0
PCI error: Failed to map BARs 0 for EC 30
```

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- [1] MRF Technical Reference. *Event System with Delay Compensation Technical Reference Firmware 0205*, April 26, 2016.
- [2] Michael Davidsaver. *EVR User Guide*, August, 2015. URL <http://epics.sourceforge.net/mrfioc2/evr-usage.pdf>.